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A PHASE CORRECTION SYSTEM FOR RADAR TRANSMITTING TUBES.(U)
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B. Loesch

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LEXINGTON, MASSACHUSETTS

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FOR THE COMMANDER

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

A PHASE CORRECTION SYSTEM FOR RADAR TRANSMITTING TUBES

B. LOESCH
Group 36

TECHNICAL REPORT 559

29 APRIL 1981

LEXINGTON MASSACHUSETTS

ABSTRACT

A phase correction system for wide-band high-powered transmitting tubes is described. This system consists of a phase modulator inserted ahead of the transmitting tube and a phase detector connected with a small coupling coefficient to the output, and with a reference signal obtained through a parallel constant time delay path equal to the average value of the delay through the tube. The phase detector output is then amplified and used to drive the phase modulator so as to approximately cancel the nonconstant time delay characteristic of the tube. Such a system should eliminate the need for a transversal equalizer.

A model transmitting tube was constructed and experimental tests are shown to prove the validity of this idea.

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I. TRANSMITTER PHASE CORRECTION SYSTEM

Many modern radar systems require hundreds of MHz of bandwidth through the transmitting and receiving signal paths. In the receiving path, the required bandwidth can usually be obtained with sufficiently low distortion to produce good signal response. However, in the high powered tubes of a transmitter there is often signal distortion, and this distortion can not be practically corrected at the high power level. Instead, the amplitude and phase distortions in the transmitted signal path are corrected (when necessary) by means of a transversal equalizer which is usually placed in the receive path.

Although transversal equalizers are effective in correcting radar signal distortion, they are expensive to construct and they require many amplitude-phase controls which must be manually adjusted. This adjustment procedure can be time consuming and tedious.

In this report an automatic phase correction system added to the transmitting signal path so that phase distortions are greatly reduced is described. Such an automatic system might then eliminate the need for any transversal equalizer.

In order to examine the feasibility of this system the characteristics of an actual transmitting tube are considered. Figures 1 and 2 show the phase-amplitude characteristics for typical VA-146N klystron tubes as are used in the ALCOR radar system. From these figures it may be noted that the saturated amplitude

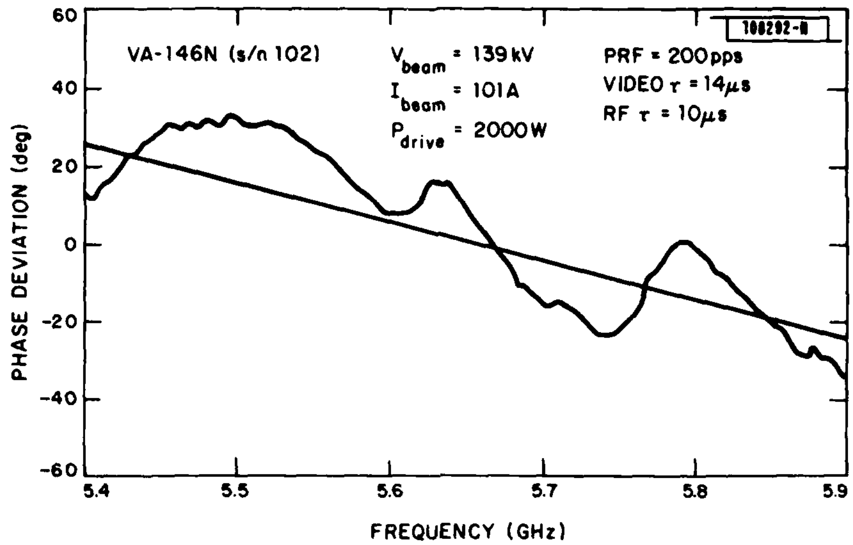

Fig. 1. Phase deviation vs frequency for a typical VA-146N. TWYSTRON.

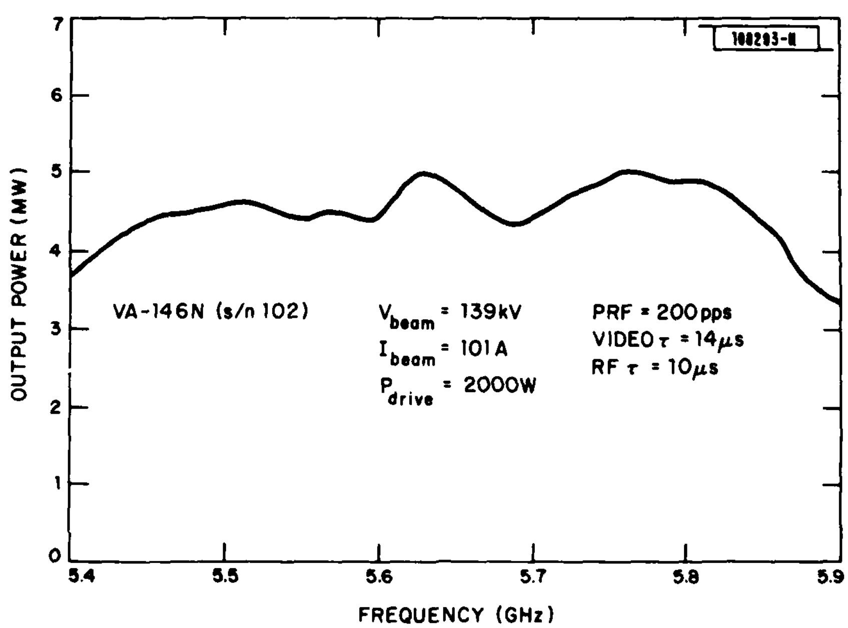

Fig. 2. Output power vs frequency for a typical VA-146N. TWYSTRON.

characteristic deviates only ±0.9 dB from a constant value over a 500 MHz bandwidth; this deviation should result in only a small and acceptable distortion. However, the phase deviates about ±18 degrees from a linear delay in an approximate cyclical fashion, and this would result in considerable distortion. It is thus argued that a phase correction system applied to this tube should much improve radar performance.

Figure 3 shows a block diagram of the phase correction system. From the diagram the system consists simply of a phase modulator inserted ahead of the transmitting tube and a phase detector connected with a small coupling coefficient to the output, and with a reference signal obtained through a parallel constant time delay path equal to the average value of the delay through the tube. The phase detector output is then amplified and used to drive the phase modulator so as to approximately cancel the non-constant time delay (phase distortion) characteristic of the tube.

It appears that this system could be practically implemented because the phase correction would be made at relatively low power level ahead of the transmitting tube. In order to demonstrate the feasibility of this idea, an experimental system was constructed.

II. DESIGN OF A SIMULATED TRANSMITTING TUBE

Since a high-powered transmitting tube was not available for experimental use, it was decided to construct a low-powered model with similar phase distortion characteristics. This model should

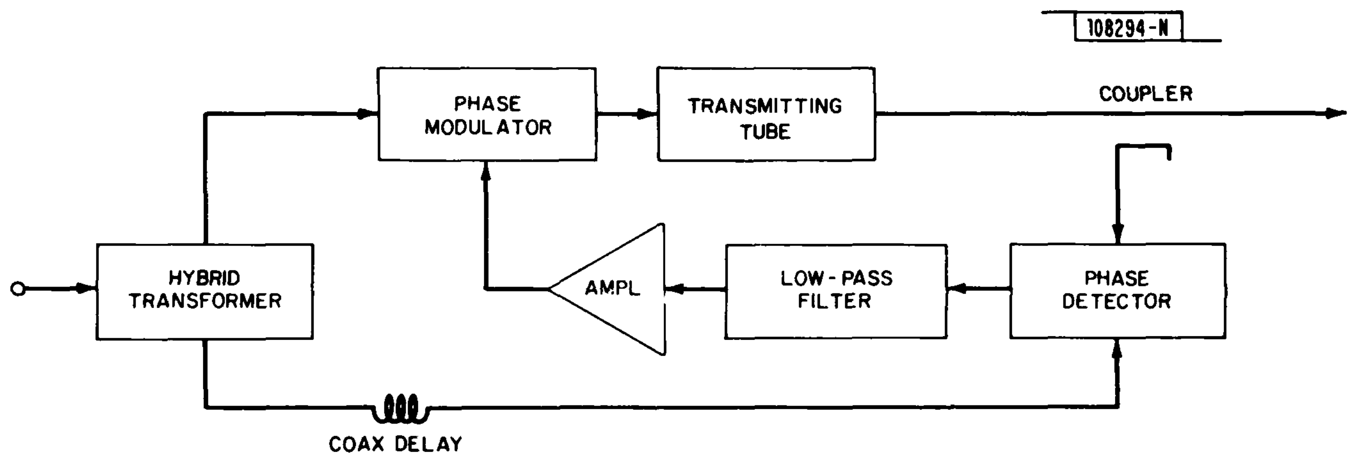

Fig. 3. Transmitting tube phase correction system.

have an approximately constant amplitude but a cyclical phase characteristic versus frequency.

In Fig. 4 is shown a block diagram of the circuit used to produce the desired frequency response. In this diagram the input signal is split into two components 90^{o} apart in phase. One of these components is attenuated by 6 dB and is then split again into equal in-phase components by a hybrid transformer; these two attenuated components pass through coax delays of length $\lambda_o/4$ and $(4n - 1)\ \lambda_o/4$ (where n is an integer) and are then summed in a hybrid transformer. The other 90^{o} component is passed through a line length of $n\ \lambda_o/2$ and is then summed with the other two.

The transmission characteristic for this circuit can be obtained as follows:

$$E_o = \frac{1}{\sqrt{2}}\left[\frac{1}{\sqrt{2}}(E_a + E_b) + E_c\right]$$

$$E_o = \frac{E_i}{\sqrt{2}}\left[\frac{j}{4\sqrt{2}}\, e^{-2\pi jf(1/4f_o)} + \frac{j}{4\sqrt{2}}\, e^{-2\pi jf(4n-1)/4f_o} + \frac{1}{\sqrt{2}}\, e^{-2\pi jf(n/2f_o)}\right]$$

$$\frac{E_o}{E_i\ e^{-2\pi jf(n/2f_o)}} = \left[\frac{1}{2} + \frac{j}{8}\, e^{-2\pi jf(1/4f_o\ -\ 2n/4f_o)} + \frac{j}{8}\, e^{-2\pi jf\left[(4n-1)/4f_o\ -\ 2n/4f_o\right]}\right]$$

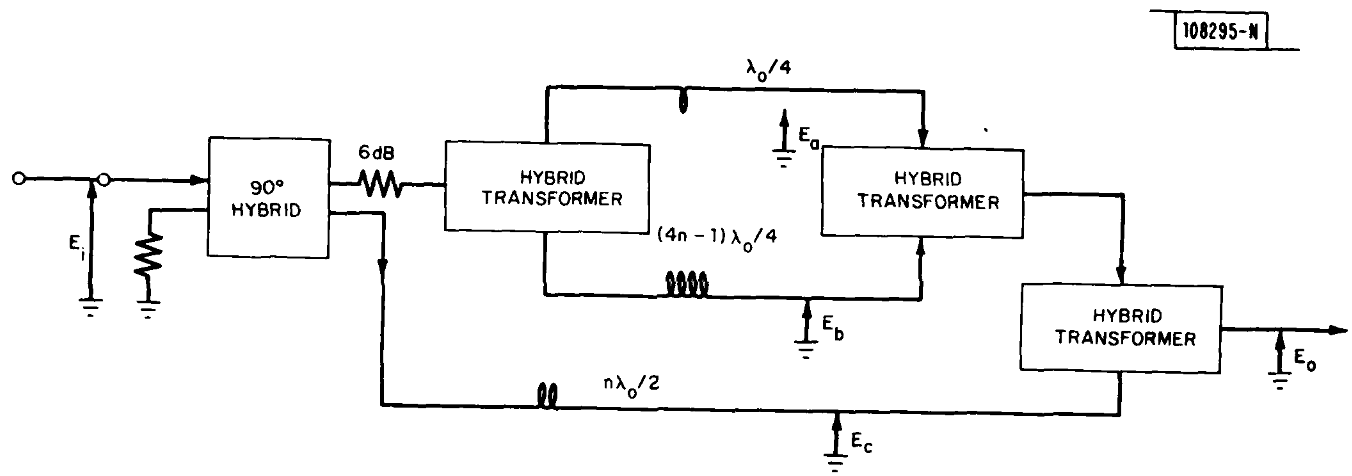

Fig. 4. Block diagram of circuit for producing cyclical phase distortion.

$$= \frac{1}{2} + \frac{j}{8} e^{+2\pi j f\,(2n-1)/4f_o} + \frac{j}{8} e^{-2\pi j f\,(2n-1)/4f_o}$$

$$= \frac{1}{2} + \frac{j}{4} \cos 2\pi f \frac{2n-1}{4f_o}$$

From the above equations, the transmission amplitude for this circuit varies from a maximum of 0.56 to a minimum of 0.50 (approximately ±0.5 dB) but the phase, relative to a reference delayed through a line length of $n\lambda_o/2$, varies by ±26.6 degrees over a frequency interval of $4f_o/(2n-1)$.

For this model circuit n was chosen to be 13 and f_o was chosen equal to 1000 MHz. The phase should then vary approximately $\pm 26^o$ over a frequency interval of 160 MHz, and there should be slightly more than 3 cycles of phase variation over a 500 MHz bandwidth.

III. EXPERIMENTAL SYSTEM TEST ARRANGEMENT

A block diagram of the experimental system test arrangement is shown in Fig. 5. The phase modulator in the upper left of the diagram is made in standard fashion using a hybrid transformer, a balanced mixer, and a 90^o hybrid coupler as shown. The 9 inch length of coax line matches the delay through the balanced mixer so as to preserve in-phase relationship of the two inputs to the 90^o hybrid.

The simulated transmitting tube circuit has already been described in principle. The practical implementation of this circuit requires that attenuator pads be placed as shown to compensate for

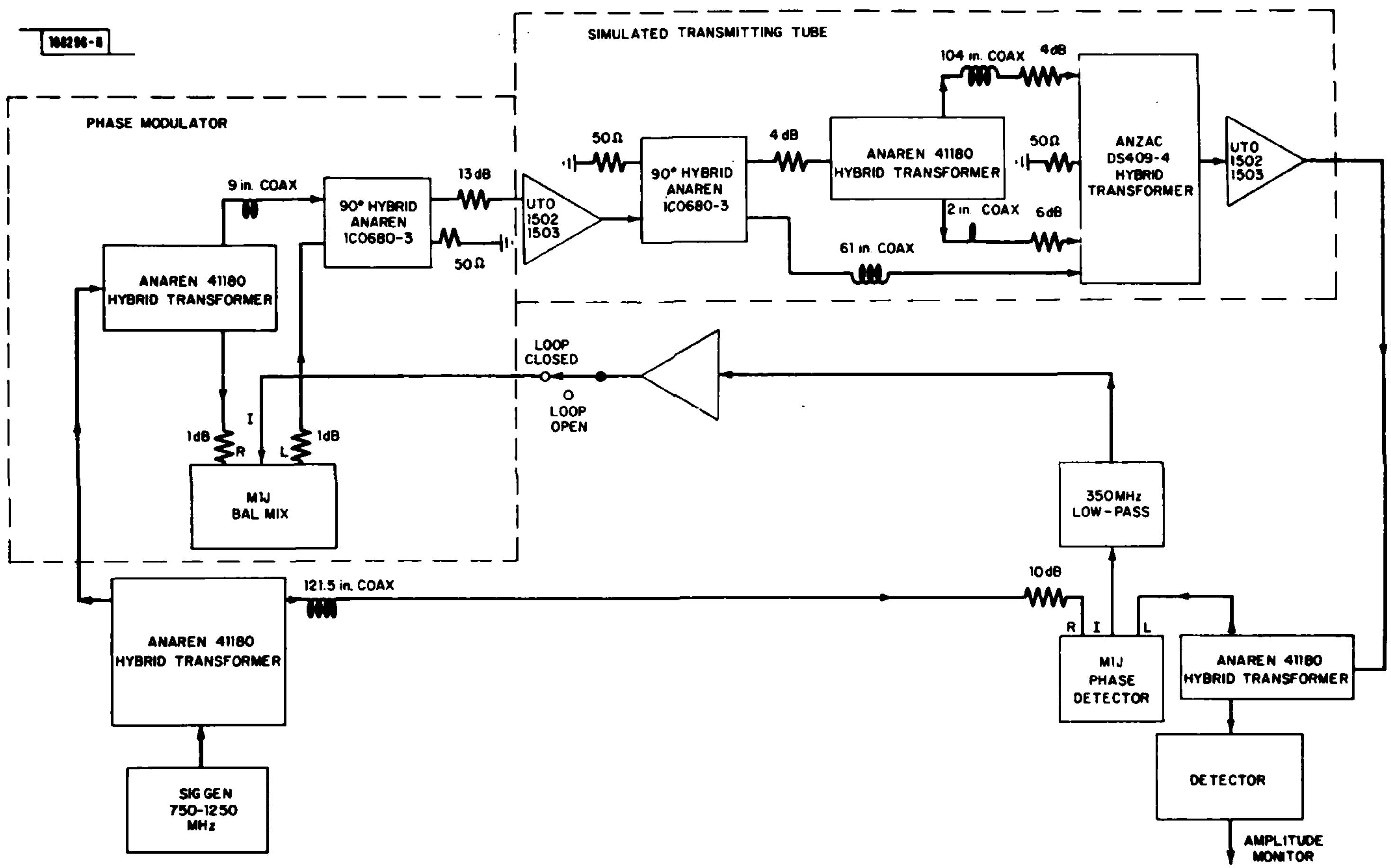

Fig. 5. Experimental system test arrangement.

coax line losses. In addition, two amplifiers have been inserted to make up for the modulator and simulated tube losses.

The transmitting tube output is connected to a hybrid power divider with one output being detected to monitor amplitude, and the other output being connected to a phase detector. The phase detector reference signal is obtained from the test system input through 121.5 inches of teflon coax line; this length of line matches the average delay through the phase modulator and the simulated transmitting tube.

The phase detector output is connected through a low pass filter to a d.c. coupled amplifier and then back to the phase modulator to close the loop. It may be noted that this closed loop does not contain an integrator and therefore the static phase error cannot be reduced to zero. It can however be reduced to an acceptably low value by a high gain amplifier.

IV. SYSTEM MEASUREMENTS

A plot of the measured amplitude-phase characteristics of the phase modulator and the simulated transmitting tube are shown in Fig. 6. This data was measured with a vector voltmeter with the loop open. It may be noted that the amplitude is essentially constant but the phase varies about ±25 degrees from an average value. This data is similar to that of an actual transmitting tube as shown in Fig. 1.

Now with the phase detector connected, Fig. 7 shows a double exposure picture of the phase detector output with the loop open

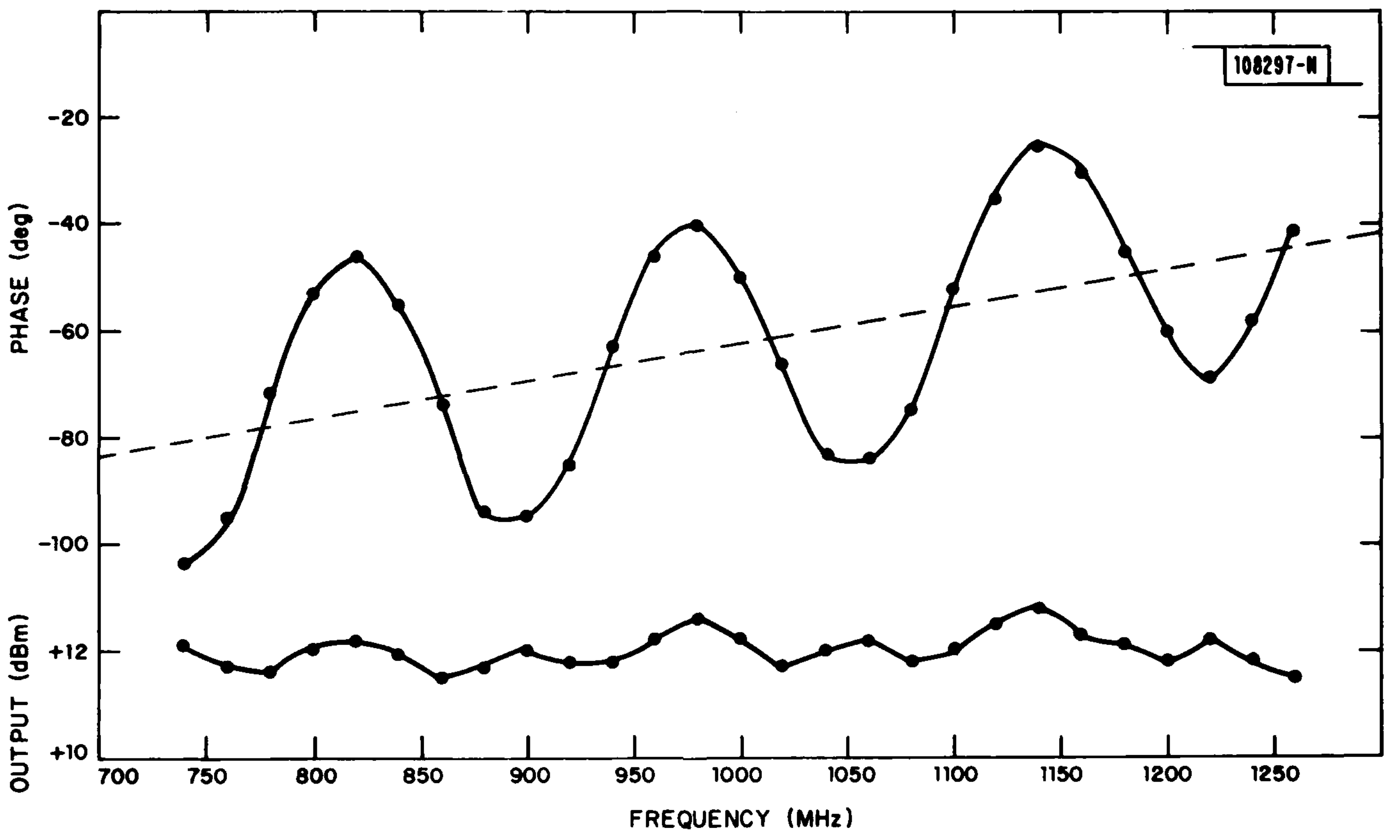

Fig. 6. Simulated transmitting tube amplitude-phase characteristic.

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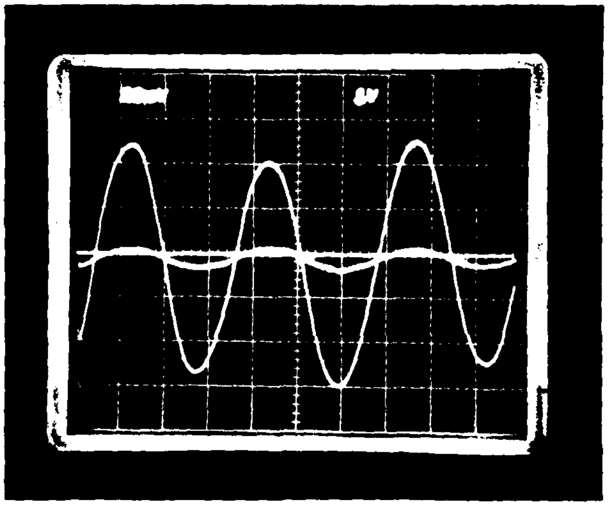

Fig. 7. Double-exposure picture of phase detector output with loop open and with it closed.

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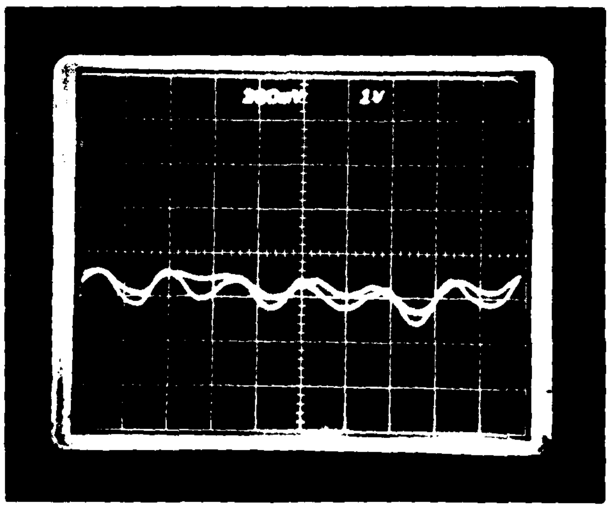

Fig. 8. Double-exposure picture of detected amplitude output with loop open and with it closed.

and with the loop closed when the input frequency is swept from 750 to 1250 MHz. With the loop open, the phase deviates about ±25 degrees (as measured by the vector voltmeter), and with the loop closed this deviation is reduced by a factor of about 12 to approximately ±2.0 degrees. Thus the phase distortion produced by the transmitting tube is greatly reduced.

In Fig. 8 is shown a double exposure picture of the detected output from the simulated transmitting tube over the frequency range from 750 to 1250 MHz with the loop open and with it closed. It will be noted that in both cases the output is essentially constant and the difference is insignificant. It is therefore concluded that the phase modulator does not produce undesired amplitude modulation.

V. LOOP FREQUENCY RESPONSE

The preceding measurements show that the simulated phase distortion can be corrected by the feedback loop for the observed frequency sweep rate. However, this rate from a laboratory frequency sweeper is several orders of magnitude less than the sweep rate of most practically useful chirp radar signals. The question should therefore be raised as to what loop frequency response would be required in an actual system. An approximate answer to this question can be obtained by reasoning that with three cycles of phase distortion in a chirp pulse length, τ, the loop frequency response must be at least $3/\tau$. Thus with a 10 microsecond pulse length, a loop response bandwidth of at least 300 KHz would be required.

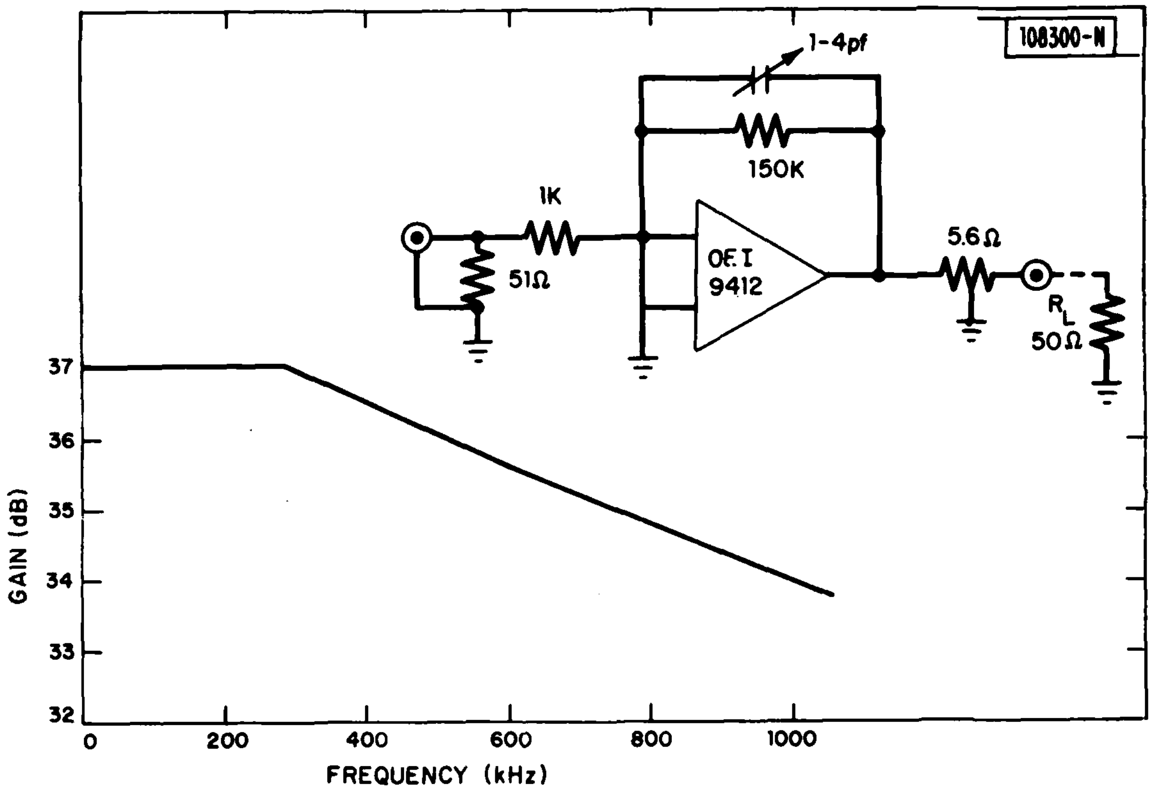

Fig. 9. Amplitude characteristics of feedback amplifier.

In the system described here, the feedback amplifier used was an OEI 9412 operational amplifier connected as shown in Fig. 9 and with the measured gain-frequency response as shown. It will be noted that the frequency response is flat only to 300 KHz which is considered marginally acceptable. Both a higher gain and a wider bandwidth amplifier would be desirable and should be achievable.

VI. CONCLUSION

Although the tests described in this report were carried out on a simulated model rather than an actual transmitting tube, these tests show that phase distortion can be reduced to an acceptable level. This gain in radar system performance can be achieved by the feedback loop which automatically compensates for aging or other transmitter changes, and is thus in contrast to a transversal equalizer which has a limited range and which must have its many controls manually adjusted.

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A phase correction system for wide-band high-powered transmitting tubes is described. This system consists of a phase modulator inserted ahead of the transmitting tube and a phase detector connected with a small coupling coefficient to the output, and with a reference signal obtained through a parallel constant time delay path equal to the average value of the delay through the tube. The phase detector output is then amplified and used to drive the phase modulator so as to approximately cancel the nonconstant time delay characteristic of the tube. Such a system should eliminate the need for a transversal equalizer.

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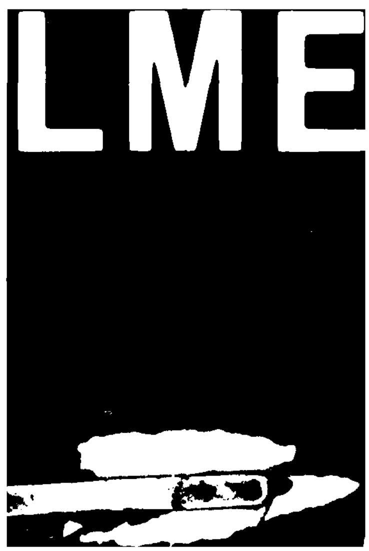
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